

UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON

Letter
Circular
LC-502C

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FIRE RESISTANCE TESTS OF LOW-COST HOUSING CONSTRUCTIONS

I. PURPOSE

The objectives, procedure, and scope of the research program on building materials have been outlined in Letter Circular LC-502. The present circular describes the details of the work planned on the fire resistance of wall, partition, floor, and roof constructions and on fire tests of roofing materials and materials used for interior and exterior finish.

The general purpose of the tests on fire resistance is to determine (1) the constructions passing the minimum requirements for use in locations where, by law or ordinance, a certain degree of fire resistance is required, (2) to determine the fire resistive properties of constructions used in locations for which there are no legal requirements relative to fire resistance but where generally some degree of protection is desirable, and (3) to determine the degree of flammability of materials used as interior or exterior covering or finishes for building constructions.

The legal requirements are concerned mainly with constructions serving as party or fire walls, as exterior walls built within a certain distance from the lot line or adjacent building, as floors separating family units in multiple-unit dwellings, and as floors or walls separating spaces such as garages, stores, or other commercial occupancies, from adjacent rooms or apartments.

In residential construction some degree of fire separation is obtained between adjacent rooms or stories usually with plastered partitions and floor constructions. For change to new types not involving plaster, it would be desirable to attain at least the protection obtained with conventional constructions.

While there are few legal requirements relating to flammability of interior finishes in residential construction, considerations of safety as well as permanence indicate the desirability of placing limits on the flammability of the materials used. As concerns exterior finishes, the legal requirements apply mainly only for roof coverings and for exterior walls where the building is within a given distance from the lot line or in other than isolated locations or very sparsely built-up sections of towns and cities. Here again considerations of safety as well as permanence indicate that the choice in materials should take into account the fire hazard presented.

From the standpoint of fire resistance requirements, tests that have been well standardized and are generally accepted can be applied to determine the properties of constructions such as walls, partitions, and floor and roof constructions. In defining the limits of acceptable constructions, some consideration must be given to the severity of fires that can occur in residential buildings. The tests made at this Bureau, supplemented by surveys of weights of combustible contents, indicate that the amount of combustible building contents associated with residential occupancies seldom exceeds 10 to 15 lb per sq ft assumed uniformly distributed over the floor area, and the average would be considerably below 10 lb per sq ft. The fire severity tests show that combustibles in this amount can give rise to fires of severity equivalent to the first 1 or 1 1/2 hr of the furnace test applied to determine the fire resistive properties of building constructions. This severity would be exceeded only in spaces used for concentrated storage of combustible household goods or similar effects.

As concerns floor and wall constructions used in locations where no definite fire resistance requirements are generally prescribed, ability to restrict spread of fire for 15 min to 1/2 hr represents what is now obtained with the less resistive plaster constructions. It is believed that such minimums might well be observed in connection with any new types proposed to be applied.

With regard to tests for flammability of interior and exterior finishes, the properties of roofing materials in this respect have been fairly well defined by tests conducted at the National Bureau of Standards and elsewhere and the different materials have been classified from this standpoint.

Tests for other finishes have also been developed such as those incorporated in Federal Specifications SS-T-302 for acoustical tile, further descriptions of which will be included in this circular.

II. WALLS AND PARTITIONS

During the first year, the work on walls and partitions will be devoted largely to constructions used for low-cost apartments and other types of multi-family dwellings.

Data on the fire resistance of conventional types of solid and hollow masonry constructions used for party, fire, and exterior walls are available and further tests thereon are not necessary (Bureau of Standards Research Paper No. 37, and Letter Circulars Nos. 228 and 229). In an effort to reduce the cost of masonry construction, several new types of hollow units are being promoted that take the place of a certain number of bricks and present a finished exterior and, for some of them, also a finished interior

surface. Some tests of constructions employing such units may be desirable. We also have data from fire tests of a considerable range of interior plastered wood and metal-framed partitions and walls, and of a few having board facings without plaster. Further tests are needed of the latter types as also of a number of less conventional solid and hollow types not faced with plaster.

1. Method of Testing

For description of methods of testing, reference is made to American Standard A.S.A. No.:A2-1934, Standard Specifications for Fire Tests of Building Construction and Materials, developed under the joint sponsorship of the National Bureau of Standards, the A.S.A fire protection group, and the American Society for Testing Materials. The wall or partition is placed to form one side of the chamber of a gas-fired furnace, the fire within which is controlled to give indicated temperatures near 1000°F at 5 min, 1300°F at 10 min, 1550°F at 30 min, 1700°F at 1 hr, 1850°F at 2 hr, and a rise of 75°F per hr thereafter. The fire endurance test is continued until the wall or partition fails due to failure under load applied for bearing walls and partitions, transmission of flame to the unexposed side, or of temperatures high enough to endanger combustible materials in contact therewith. In the fire and hose stream test, required only for constructions withstanding the fire endurance test for 1/2 hr or more, the fire exposure is continued for a period equal to one-half of that applied in the fire endurance test, after which a hose stream is played over the fire-exposed surface, the duration and force of which is proportioned to the size of the construction and the fire endurance developed.

2. Specimens

The Bureau's furnace equipment accommodates specimens up to 16 ft wide and 10 to 11 ft high. Where the differences in details of constructions are not considerable, two or more variations might be included in the same test panel. Where a fire resistance of 1/2 hr or more is developed or required, the minimum would be two specimens, one to be subjected to a fire endurance test to failure, and the other to a fire and hose stream test.

III. FLOOR AND ROOF CONSTRUCTIONS

There is very little experimental data extant on the fire resistance of floor and roof constructions as tested by the methods given in the specifications cited above.

1. Method of Testing

The test involves fire exposure on the lower side of the floor in a gas-fired furnace, which is continued in the fire endurance

test until failure occurs under the applied load or until there is passage of flame or unduly high temperatures to the upper face. A hose stream test is applied similar to that indicated above for walls and partitions.

2. Specimens

The Bureau's furnace accommodates specimens up to 13 1/2 ft wide and 18 ft long. For minor differences in details of construction, 2 or 3 variations might be included in the same test panel where only the properties of the floor slabs and not of the supporting beams are involved. Where a fire resistance of 1/2 hr or more is developed or required, there are required at least two tests, the specimens for which would aggregate in size the full dimensions accommodated by the furnace, one to be a fire endurance test to failure and the other a fire and hose stream test.

IV. FIRE TESTS OF ROOFING MATERIALS

New types of materials used for roof covering will be subjected to brand, flame, and spread tests under controlled conditions, to determine their classification from the fire hazard standpoint.

1. Methods of Testing

(a) Brand Tests

The material is subjected to burning brands of initial weight from a fraction of a gram to 2000 grams, with air currents over the deck of 6 and 12 miles per hr velocity, the criterion of performance being the absence of ignition of the wood or other combustible sheathing on which the material is mounted.

(b) Flame Tests

A standardized flame is applied over the lower portion of the specimen, the criterion of performance being the time required for flame to appear on the lower surface of the supporting sheathing or deck. The extent to which burning brands are thrown off with given air velocities over the deck is also a criterion.

(c) Spread Tests

A standardized flame is applied over the lower portion of the specimen, the criterion of performance being the time required for flame to spread to certain distances above the base of the deck. The extent to which burning brands are thrown off with given air velocities over the deck is also a criterion.

2. Specimens

For the brand tests three representative decks 3 ft 4 in. wide and 4 ft long are required. For the flame tests two similar decks of the same size are needed, and for the spread tests two decks 3 ft 4 in. wide and 12 ft long.

V. FIRE TESTS OF FINISH FOR WALLS, PARTITIONS, AND CEILINGS

1. Methods of Testing

The materials are classified as "Incombustible", "Fire Retardant", "Slow-Burning", or "Combustible", as based on performance in the tests. The samples are mounted in a horizontal position and subjected at the center to a flame from a gas-air burner of 7/8 in. tube diameter, the severity of the exposure being gauged by temperature measurements 1 in. below the surface of the specimen immediately above the flame, and the maximum area of the specimen to be covered by the flame. For the tests for "Slow-Burning" and "Combustible" classifications, the flame is regulated to give temperature indications at the given point corresponding to those described in the specification cited above for fire tests of building materials and constructions, the duration of the test being 20 min. For the "Fire Retardant" and "Incombustible" classifications, a higher temperature rise is involved, reaching 1700°F in 1/2 hr, the test being continued for 40 min. The specimens are mounted on a square iron angle frame 30 by 30 in. inside with the finished face down.

The criterion of performance for the different classifications involves absence of flaming or, for the "Fire Retardant" and "Slow-Burning" classifications, no flaming on the specimen that reaches the angle frame at any point. The specimen must remain in place for the duration of the test except for burning, charred, or disintegrated material falling in small pieces. To qualify for the "Incombustible", "Fire Retardant" or "Slow-Burning" classifications, no glow shall progress during or after test to the edge of the specimen.

2. Test Specimens

Not less than two 3 by 3 ft specimens are required or sufficient material from which such specimens can be constructed. These are mounted on a cinder concrete slab base, using the methods of attachment recommended or appropriate for the material.

STANDARD SPECIFICATIONS
FOR
FIRE TESTS OF BUILDING
CONSTRUCTION AND MATERIALS

American Standard
A.S.A.No.: A2-1934

Prepared by the Sectional Committee on Fire Tests of Materials and Construction, under the joint sponsorship of the National Bureau of Standards, the A.S.A. Fire Protection Group and the American Society for Testing Materials, functioning under the procedure of the American Standards Association.

The performance of walls, columns, floors and other building members under fire exposure conditions is an item of major importance in securing constructions which are safe and which are not a menace to neighboring structures nor to the public. Recognition of this is registered in the codes of many authorities, municipal and other. It is important to secure balance of the many units in a single building, and of buildings of like character and use in a community; and also to promote uniformity in requirements of various authorities throughout the country. To do this it is necessary that the fire-resistive properties of materials and assemblies be measured and specified according to a common standard expressed in terms which are applicable alike to a wide variety of materials, situations and conditions of exposure.

Such a standard is found in the specifications which follow. They prescribe a standard exposing fire of controlled extent and severity. Performance is defined as the period of resistance to standard exposure elapsing before the first critical point in behavior is observed. Results are reported in units in which field exposures can be judged and expressed.

The specifications may be cited as the "Standard Fire Test Specification" and the performance or exposure shall be expressed as "2-hour", "6-hour", "1/2-hour", etc.

When a factor of safety exceeding that inherent in the test conditions is desired, a proportional increase should be made in the specified time-classification period.

Classifications of assemblies involving combustibles in such kind or quantity or so contained as to burn freely during the exposure to the test fire or continue flaming after the furnace is shut off shall be designated by the term "combustible" after the period assigned.

Scope

1. (a) The test methods are applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams and slabs and composite slab and beam assemblies for floors and roofs. They are also applicable to other assemblies and structural units which constitute permanent integral parts of a finished building.

(b) It is the intent that classifications shall register performance during the period of exposure and shall not be construed as having determined suitability for use after fire exposure.

CONTROL OF FIRE TESTS

Time-Temperature Curve

2. The conduct of fire tests of materials and construction shall be controlled by the standard time-temperature curve shown in fig 1. The points on the curve which determine its character are:

1000°F (approximately 538°C)	.....	at 5 min
1300°F (approximately 704°C)	.....	at 10 min
1550°F (approximately 843°C)	.....	at 30 min
1700°F (approximately 927°C)	.....	at 1 hr
1850°F (1010°C)	.....	at 2 hr
2000°F (approximately 1093°C)	.....	at 4 hr
2300°F (1260°C)	.....	at 8 hr or over

Determination of Furnace Temperatures

3. (a) The temperature fixed by the curve shall be deemed to be the average temperature obtained from the readings of several thermocouples (not less than three) symmetrically disposed and distributed to show the temperature near all parts of the sample, the thermocouples being inclosed in sealed porcelain tubes $\frac{3}{4}$ in. in outside diameter and of $\frac{1}{8}$ in.-wall thickness. The exposed length of the porcelain tube and couple in the furnace chamber shall be not less than 12 in. Other types of protecting tubes or pyrometers may be used that under test conditions give the same indications as the above standard within the limit of accuracy that applies for furnace-temperature measurements. For greater difference of design and size the time-temperature curve followed shall be modified to give an exposure equal to that obtained by using the standard pyrometer and curve above described.

(b) The temperatures shall be read at intervals not exceeding 5 min during the first hour, and thereafter the intervals may be increased to not more than 15 min.

(c) The accuracy of the furnace control shall be such that the area under the time-temperature curve, obtained by averaging the results from the pyrometer readings, is within 15 percent of the corresponding area under the standard time-temperature curve shown in fig 1 for fire tests of one hour or less duration; within 10 percent for those over one hour and not more than two hours; and within 5 percent for tests exceeding two hours in duration.

Determination of Temperatures of Unexposed Surfaces of Floors, Walls and Partitions

4. (a) Temperatures at unexposed surfaces shall be measured with thermocouples or thermometers¹ placed under flexible, oven-dry, felted asbestos pads 6 in. square, 0.4 in. in thickness, and weighing not less than 1.0 nor more than 1.4 lb per sq ft. The pads shall be sufficiently soft so that, without breaking, they may be shaped to contact over the whole surface against which they are placed. The wire leads of the thermocouple or the stem of the thermometer shall have an immersion under the pad and be in contact with the unexposed surface for not less than 3 1/2 in. The hot junction of the thermocouple or the bulb of the thermometer shall be placed approximately under the center of the pad. The outside diameter of protecting tubes of glass, clay or porcelain, and of thermometer stems, shall not be more than 5/16 in. The pad shall be held firmly against the surface, and shall fit closely about the thermocouples or thermometer stems. Thermometers shall be of the partial-immersion type, with a length of stem, between the end of the bulb and the immersion mark, of 3 in. The wires for the thermocouple in the length covered by the pad shall not be heavier than No. 18 B & S gage (0.04 in.) and shall be electrically insulated with heat- and moisture-resistant coatings.

(b) The temperature readings shall be taken at not less than five points on the surface, one of which shall be approximately at the center, and four at approximately the centers of the quarter sections. If additional points are used they shall be symmetrically disposed about the center, with no location nearer than 1 1/2 times the thickness of the construction, or nearer than 12 in., to the edges. None shall be located opposite or on top of beams, girders, pilasters or other structural members.

(c) Temperature readings shall be taken at intervals not exceeding 15 min. until a reading exceeding 212°F (100°C) has been obtained at any one point. Thereafter the readings may be taken more frequently at the discretion of the testing body, but the intervals need not be less than 5 min.

¹Under certain conditions it may be unsafe or impracticable to use thermometers.

(d) Where the Conditions of Acceptance place a limitation on the rise of temperature of the unexposed surface, the temperature end point of the fire endurance period shall be determined by the average of the measurements taken at individual points; excepting that if a temperature rise 30 percent in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire endurance period judged as ended.

CLASSIFICATION AS DETERMINED BY TEST

5. Results shall be reported in accordance with the performance in the tests prescribed in these specifications. They shall be expressed in time periods of resistance, as for example 4-hour, 1/2-hour, etc.

TEST STRUCTURES

6. (a) The test structure may be located at any place where all the necessary facilities for properly conducting the test are provided.

(b) Entire freedom is left to each investigator in the design of the test structure and the nature and use of fuel, provided the test requirements are met.

TEST SAMPLES

7. The test sample shall be truly representative of the construction for which classification is desired as to materials, workmanship, and details such as dimensions of parts, and shall be built under conditions representative of those obtaining as practically applied in building construction and operation. The physical properties of the materials and/or ingredients used in the test sample shall be determined and recorded.

CONDUCT OF FIRE TESTS

Fire Endurance Test

8. The fire endurance test on the sample with its applied load, if any, shall be continued until failure occurs, or until it has withstood the test conditions for a period equal to that herein specified in the Conditions of Acceptance for the given type of construction.

Hose Stream Test

9. (a) Where required by the Conditions of Acceptance, a duplicate sample shall be subjected to a fire exposure test for a period equal to one-half of that indicated as the resistance period in the fire endurance test, but not for more than one hour, immediately after which the sample shall be subjected to the impact, erosion and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed face, changes in direction being made slowly.

Exemption

(b) The hose stream test shall not be required in the case of constructions having a resistance period, indicated in the fire endurance test, of one-half hour or less.

Optional Program

(c) The submittor may elect, with the advice and consent of the testing body, to have the hose stream test made on the sample subjected to the fire endurance test and immediately following the expiration of the fire endurance test.

Hose Stream Equipment and Details

(d) The stream shall be delivered through 2 1/2-in. hose, discharging through a National Standard Playpipe of corresponding size equipped with a 1 1/8-in. discharge tip of the standard taper smooth-bore pattern without shoulder at the orifice. The water pressure and duration of application shall be as specified in table I.

TABLE I.

Parts of Structure	Resistance Period	Water Pressure at Nozzle lb per sq in.	Duration of Application, minutes per 100 sq ft exposed area
Floors and Roofs	8 hours and over	45	6
	4 hours and over if less than 8 hours	45	5
	2 hours and over if less than 4 hours	45	2 1/2
	1 hour and over if less than 2 hours	30	1 1/2
	Less than 1 hour	30	1
Walls and Partitions	8 hours and over	45	6
	4 hours and over if less than 3 hours	45	5
	2 hours and over if less than 4 hours	30	2 1/2
	1 hour and over if less than 2 hours	30	1 1/2
	Less than 1 hour	30	1

Nozzle Distance

(e) The nozzle orifice shall be 20 ft from the center of the exposed surface of the test sample if the nozzle is so located that when directed at the center its axis is normal to the surface of the test sample. If otherwise located its distance from the center shall be less than 20 ft by an amount equal to 1 ft for each 10 deg. of deviation from the normal.

Time of Testing

10. The material or construction shall not be tested until a large proportion of its final strength has been attained, and, if it contains free water, until the excess has been given off; this will usually require about 30 days' time under favorable drying conditions. Artificial drying at temperatures not injurious to the material or construction to be tested may be used.

TESTS OF BEARING WALLS AND PARTITIONS

Size of Sample

11. The area exposed to fire shall be not less than 100 sq. ft, with neither dimension less than 9 ft. The test specimen shall not be restrained on its vertical edges.

Loading

12. During the fire endurance and fire and hose stream tests the construction shall be loaded in a manner calculated to develop theoretically as nearly as practicable the working stresses contemplated by the design.

Conditions of Acceptance

13. The test shall not be regarded as successful unless the following conditions are met:

(a) The wall or partition shall have sustained the applied load during the fire endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.

(b) The wall or partition shall have sustained the applied load during the fire and hose stream test as specified in Section 9, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream, and after cooling but within 72 hr after its completion shall sustain a total load equal to the dead load plus twice the superimposed load specified above.

(c) The fire-stopping, if any, shall have functioned to prevent passage of fire for a period equal to that for which classification is desired.

(d) Transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

TESTS OF NON-BEARING WALLS AND PARTITIONS

Size of Sample

14. The area exposed to fire shall be not less than 100 sq ft with neither dimension less than 9 ft. The test specimen shall be restrained on all four edges.

Conditions of Acceptance

15. The test shall not be regarded as successful unless the following conditions are met:

(a) The wall or partition shall have withstood the fire endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.

(b) The wall or partition shall have withstood the fire and hose stream test as specified in Section 9, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream.

(c) The fire-stopping, if any, shall have functioned to prevent passage of fire for a period equal to that for which classification is desired.

(d) Transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

TESTS OF COLUMNS

Size of Sample

16. The length of the column exposed to fire shall, when practicable, approximate the maximum clear length contemplated by the design, and for building columns shall not be less than 9 ft. The contemplated details of connections, and their protection, if any, shall be applied according to the methods of acceptable field practice.

Loading

17. (a) During the fire endurance test the column shall be exposed to fire on all sides and shall be loaded in a manner calculated to develop theoretically as nearly as practicable the

working stresses contemplated by the design. Provision shall be made for transmitting the load to the exposed portion of the column without unduly increasing the effective column length.

(b) If the submittor and the testing body jointly so decide, the column may be subjected to $1\frac{3}{4}$ times its designed working load before the fire endurance test is undertaken. The fact that such a test has been made shall not be construed as having had a deleterious effect on the fire endurance test performance.

Condition of Acceptance

18. The test shall not be regarded as successful unless the column shall have sustained the applied load during the fire endurance test for a period equal to that for which classification is desired.

TESTS OF FLOORS AND ROOFS

(The following contemplates application of fire exposure to the under side of constructions and omission from the upper surface of all units which are not essential to the constructions. Specifications and test procedure with fire applied to the upper side have not been developed.)

Size of Sample

19. The area exposed to fire shall be not less than 180 sq ft with neither dimension less than 12 ft. Beams or girders if a part of the construction under test shall lie within the combustion chamber and have a clearance of not less than 8 in. from its walls.

Loading

20. During the fire endurance and fire and fire stream tests the construction shall be loaded in a manner calculated to develop theoretically as nearly as practicable the working stresses in each member contemplated by the design.

Conditions of Acceptance

21. The test shall not be regarded as successful unless the following conditions are met:

(a) The construction shall have sustained the applied load during the fire endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.

(b) The construction shall have sustained the applied load during the fire and hose stream test as specified in Section 9, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream, and after cooling but within 72 hr after its completion shall sustain a total load equal to the dead load plus twice the superimposed load specified above.

(c) Transmission of heat through the construction during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

TESTS OF FINISH FOR COMBUSTIBLE FRAMING OR FACINGS OF WALLS, PARTITIONS AND CEILINGS

Character of Sample

22. The test panel shall be a wall, partition or floor.

(a) Test panels carrying interior wall and partition finish shall be finished on both faces with the finish which is the subject of the test; excepting that with the advice or consent of the testing body this provision may be waived with respect to panels of solid construction.

(b) Test panels carrying exterior wall finish on the exposed face shall be finished on the unexposed face with an interior wall finish judged by the testing body to be suitable for purposes of the test; excepting that with the advice or consent of the testing body this provision may be waived with respect to panels of solid construction.

(c) Test panels carrying ceiling finish shall be finished on the upper face with a flooring judged by the testing body to be suitable for purposes of the test; excepting that with the advice or consent of the testing body this provision may be waived with respect to panels of solid construction.

Size of Sample

23. The area exposed to fire shall be for tests of wall and finish, not less than 100 sq ft, with neither dimension less than 9 ft; for tests of ceiling finish, not less than 180 sq ft, with neither dimension less than 12 ft.

Conditions of Acceptance

24. The test shall not be regarded as successful unless the following conditions are met:

(a) The finish shall have withstood the fire endurance test, without passage of flame or of gases hot enough to ignite the materials protected, for a period equal to that for which classification is desired.

(b) The finish shall have withstood the fire and hose stream test as prescribed respectively for floors, walls and partitions as specified in Section 9, without passage of flame, of gases hot enough to ignite the materials protected, or of the hose stream.

(c) Transmission of heat through the finish during the fire endurance test shall not have been such as to raise the temperatures at its contact with the structural members of the test panel or elsewhere on its unexposed surface more than 250°F (139°C) above the initial temperatures at these points.

FIGURE 1 - TIME-TEMPERATURE CURVE



